

# Neo-Davidsonian semantics

A systematic exploration of the ways Brutus can do violence to Caesar

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# The age-old question: representing sentences.

**Brutus stabs Caesar.**

# Representing sentences



“Brutus stabs Caesar.”

- How to represent this?
- Start with the predicate: stab.
- Standard first-order predicate calculus representation:
  - $\text{stab}(\text{Brutus}, \text{Caesar})$

**That was easy. Let's make it more complicated.**



**Brutus stabs Caesar with a knife.**

# Representing sentences

“Brutus stabs Caesar with a knife.”

- The knife is a participant in the action.
- Perhaps...make it an argument of the predicate?
- Possible representation:
  - stab(Brutus, Caesar, knife)
  - ...



**Brutus stabs Caesar in the agora.**



# Representing sentences

“Brutus stabs Caesar in the agora.”

- The agora is a participant in the action.
- Perhaps...make it a member of the predicate?
- Possible representation:
  - stab(Brutus, Caesar, agora)
  - ...
- But an agora is not a participant in the same way that a knife is.
  - Knife - instrument
  - Agora - location
- The predicate arguments are now ambiguous.

**Brutus stabs Caesar with a knife in  
the agora.**

# Representing sentences

“Brutus stabs Caesar with a knife in the agora.”

- The knife is a participant in the action.
- The agora is a participant in the action.
- Possible representation:
  - stab(Brutus, Caesar, agora, knife) ?
  - ...
- Uh-oh, we require a different arity for all these optional adjuncts.
- Or we need a more flexible way to represent predicates.

# Splitting it up

- “Brutus stabs Caesar with a knife in the agora.”
- Possible representation:
  - stabs(Brutus, Caesar) & with(knife) & in(agora)
- Much better now: can have arbitrary adjuncts.

Brutus stabs Caesar **with a knife** **in**  
**the agora** **and** **twists it hard.**

# Representing sentences

- “Brutus stabs Caesar with a knife in the agora and twists it hard.”
- Possible representation:
  - stabs(Brutus, Caesar) & with(knife) & in(agora) & twists(Brutus, knife) & hard
- What does the with-predicate apply to?
- What does the 0-arity hard-predicate apply to?

## Standard predicate calculus representations

- They do not allow us to refer to predicates.
- But need to refer to predicates to describe complex actions.
- Language is very flexible, predicates can have variable #s of arguments without necessarily having strongly different meanings. ("Pass (me) the salt.")
- Adverbial modifiers, relative clauses, oh my...

# A rough analogy

Consider the noun phrase: *some clever driver in America*

- Translate this into a possible logical form:

$\exists x \text{ driver}(x) \ \& \ \text{clever}(x) \ \& \ \text{location}(x, \text{America})$

- Descriptors of the entity tied together by an existentially-quantified variable  $x$ .

Consider the sentence: *Bob drives cleverly in America*

- Now there is an act of driving, rather than a driver.
- Can we still tie together the descriptors of driving?
- (The analogy doesn't quite work because a "former driver" is not a driver who is former. . . .)



## Davidson 1989 quoted in Maienborn 2010

Adverbial modification is thus seen to be logically on a par with adjectival modification: what adverbial clauses modify is not verbs but the events that certain verbs introduce.

- A verb predicate like “stab” is actually a description of an **event**.
- We need to represent this event in the semantics: an event variable.
- We don't know what it is beforehand, so we existentially quantify it.

Brutus stabs Caesar **with a knife in**  
**the agora**

=

$\exists e$  stabs( $e$ , Brutus, Caesar) &  
**with( $e$ , knife) & in( $e$ , agora)**

Now we have a flexible way to talk about the event of stabbing.

Brutus stabs Caesar **with a knife** **in**  
**the agora** **and** **twists it hard.**

=

$\exists e_1$  stabs( $e_1$ , Brutus, Caesar) &  
**with( $e_1$ , knife)** & **in( $e_1$ , agora)** &  $\exists e_2$   
**twists( $e_2$ , Brutus, knife)** & **hard( $e_2$ )**

Now we have a flexible way to talk about the event of stabbing and twisting hard.

# Alternative ways?

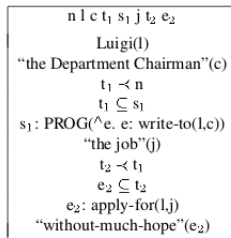
They're actually surprisingly hard to find.

- However, consider Discourse Representation Theory (DRT).

## From the “Handbook of Philosophical Logic”

Luigi was writing to the Department Chairman. He had applied for the job without much hope.

- Can view multiple sentences as one discourse:



- Events even show up here!



*Something that is Neo.*

**Q: But what makes it  
NEO-Davidsonian?**

**A: It got an update by Parsons (1990). But this requires a bit of background in semantics.**

# Thematic roles

## Active voice

Brutus stabbed Caesar.

*Brutus* is the subject of the sentence.

*Caesar* is the object of the sentence.

## Passive voice

Caesar was stabbed (by Brutus).

*Caesar* is the subject of the sentence.

*Brutus* is the object of the optional preposition *by*.



## Active voice

Brutus stabbed Caesar.

*Brutus* is the one doing the stabbing.

*Caesar* is the one getting stabbed.

## Passive voice

Caesar was stabbed (by Brutus).

*Brutus* is the one doing the stabbing.

*Caesar* is the one getting stabbed.

# Thematic roles

## Passive voice

Caesar was stabbed (by Brutus).

*Brutus* is the one doing the stabbing.

*Caesar* is the one getting stabbed.

Grammatical roles have switched, but semantic roles have not!

- There is a clear separation between *syntactic* arguments and *semantic* arguments.
- *Semantic arguments*  $\Rightarrow$  thematic roles aka  $\theta$ -roles.
- A POSSIBLE inventory of roles from Parsons (1995). Given an event  $e$  and an entity  $x$ :
  - $e$  is by  $x$  - Agent
  - $x$  experiences  $e$  - Experiencer
  - $e$  is of  $x$  - Theme
  - $e$  is from  $x$  - Source
  - ...
- The specific inventory is quite controversial but Agent and Theme are minimal members of the set.

**Caesar** was stabbed by **Brutus**.

- **Caesar** is the **Theme** (or “Patient”).
- **Brutus** is the **Agent**.

**Caesar** was stabbed by **Brutus**.

A Davidsonian representation:

- $\exists e \text{ stab}(e, \text{Brutus}, \text{Caesar})$

**Caesar** was stabbed (by **Brutus**).

But there's no way to represent the fact that the theme is optional, without an ambiguous lexical entry.

## Caesar was stabbed (by Brutus).

Solution: break predicate arguments into thematic roles.

- $\exists e \text{ stab}(e)$  (&  $\text{Agent}(e, \text{Brutus})$ ) &  $\text{Patient}(e, \text{Caesar})$
- The stab-predicate now only has the event argument.
- Optionality of agent in the passive is fully accommodated.



# Problems?

“Arcane” semantic issues mentioned by Parsons (1995).

- “I sold you a car for \$5.” – what is the Theme here, “a car” or 5?
  - The \$5 is changing hands here, so it is affected by the event.
- Ambiguous prepositions: “I sold a car for Mary for \$5.”
  - Two uses of “for” – not exactly a semantic problem for us, but Parsons thought it was.
- “Mary fed her baby” – why is “baby” not an agent? It is feeding!
  - (Consider “riechen” in German. “Es riecht” (it smells) vs “Ich rieche es” (I’m smelling it).

What about non-eventive assertions?

- “Mary is sick.”
- Need a state variable rather than an event variable.
  - $\exists s$  being-sick( $s$ ) & In( $s$ , Mary)
  - Read: “Mary is in a state of being sick.”

- “Caesar was stabbed.”
  - But what if you really wanted to include the agent?
  - No problem, quantify:  $\exists x \exists e \text{stab}(e) \ \& \ \text{Agent}(e, x) \ \& \ \text{Theme}(e, \text{Caesar})$
  - Entirely optional to do it this way. (Why would you?)
- “Destruction” vs. “destroy” – do nouns have events?
  - “the destruction of the city by God”
- Argument/adjunct distinctions. (We’ll get to this.)

**Q: But this is a seminar on  
incremental syntax/semantics.  
What does neo-Davidsonian  
semantics have to do with that?**

**I CARE ABOUT THIS ALOT**



*From Allie Brosh's famous blog.*

**A: A lot.**

# I CARE ABOUT THIS ALOT



*From Allie Brosh's famous blog.*

## A: A lot.

- Broken down the representation into atomic components of fixed arity.
- Provided way to connect them via the event variable.

Et tu, Brute? Et tu, Brute? Et tu, Brute? ...

An incremental parse:

|| Brutus often stabs Caesar.  
=

Et tu, Brute? Et tu, Brute? Et tu, Brute? ...

An incremental parse:

**Brutus** || **often** stabs **Caesar**.  
=  
 $\exists e$  **Agent**( $e$ , **Brutus**)

Et tu, Brute? Et tu, Brute? Et tu, Brute? ...

An incremental parse:

**Brutus** often || stabs **Caesar**.

=

$\exists e$  **Agent**( $e$ , **Brutus**) & often( $e$ )



Et tu, Brute? Et tu, Brute? Et tu, Brute? ...

An incremental parse:

$$\begin{array}{c} \text{Brutus often stabs} \parallel \text{Caesar.} \\ = \\ \exists e \text{ Agent}(e, \text{Brutus}) \ \& \ \text{often}(e) \ \& \\ \text{stabs}(e) \end{array}$$

Et tu, Brute? Et tu, Brute? Et tu, Brute? ...

An incremental parse:

$$\begin{array}{c} \text{Brutus often stabs Caesar.} \parallel \\ = \\ \exists e \text{ Agent}(e, \text{Brutus}) \ \& \ \text{often}(e) \ \& \\ \text{stabs}(e) \ \& \ \text{Theme}(e, \text{Caesar}) \end{array}$$

# Incremental parsing



- Previous example: big assumption that the syntactic parser will cooperate.
- The challenge: designing the syntax and the lexicon to work with the semantics.
- But: Neo-Davidsonian approach at least simplifies predicate representation.
- Low recursion: inference rules not required to go back and edit deeply embedded arguments.
- To tie it back to last class: Aist et al.

Aist et al. 2006

MOVE a: *move*(*X*, *Y*)

LARGE TRIANGLE to: *move*(*triangle1*, *Y*)

CENTRAL PARK: *move*(*triangle1*, *centralpark1*)

- Aist et al. are filling in free variables as the parse proceeds.
- How to make this flexible enough to handle more of language?

# Argument/adjunct representation issues

“Brutus stabbed Caesar violently yesterday.”

- Possible neo-Davidsonian representation:
  - $\exists e \text{ stab}(e) \ \& \ \text{Agent}(e, \text{Brutus}) \ \& \ \text{Theme}(e, \text{Caesar}) \ \& \ \text{violently}(e) \ \& \ \text{yesterday}(e)$
- Get rid of the last two
  - $\exists e \text{ stab}(e) \ \& \ \text{Agent}(e, \text{Brutus}) \ \& \ \text{Theme}(e, \text{Caesar})$
  - Still corresponds to grammatical sentence (ignoring tense): “Brutus stabbed Caesar”.
  - Doesn’t change truth condition, they’re adjuncts.

But getting rid of Brutus or Caesar definitely does. They’re arguments.

# Argument/adjunct representation issues

## Implications for the design of the parsing algorithm

- Argument-event relation mediated through thematic role.
- Verb adjuncts: direct relation.
- Syntax already usually aware of optional adjuncts—need principled way to translate to semantics.

## Hunter (2009)

- Encode the relationship directly into the minimalist grammar (MG – similar in spirit to CCG).
- Define an adjunction operation in the grammar that establishes a direct connection to the event.

Next week, we will describe a way to do this for TAG.

# Minimal recursion semantics (MRS)

Practical Davidsonian representation (Copestake, 2005 etc).

- “Elementary predications” (EPs) – Davidsonian conjuncts.
- Hooks and slots (roles and fillers) are used for semantic composition through equations (more complicated than this, of course).
- Can be attached to various grammar formalisms
- Underspecification! (we’ll deal with this next week too)

*the fat cat sat on a mat*

MRS representation:

$l0: \_the\_q(x0, h01, h02), l1: \_fat\_j(x1), l2: \_cat\_n(x2), l3: \_sit\_v\_1(e3, x3), l4: \_on\_p(e4, e41, x4),$   
 $l5: \_a\_q(x5, h51, h52), l6: \_mat\_n\_1(x6),$   
 $h01 =_q l1, h51 =_q l6$   
 $x0 = x1 = x2 = x3, e3 = e41, x4 = x5 = x6, l1 = l2, l3 = l4$

# Minimal recursion semantics (MRS)

To achieve further underspecification, can be Neo-Davidsonianized (RMRS):

RMRS equivalent to the MRS above:

```
l0: a0: _the_q(x0), l0: a0: RSTR(h01), l0: a0: BODY(h02), l1: a1: _fat_j(x1), l2: a2: _cat_n(x2),  
l3: a3: _sit_v_l(e3), l3: a3: ARG1(x31), l4: a4: _on_p(e4, e41, x4), l4: a4: ARG1(e41), l4: a4: ARG2(x4),  
l5: a5: _a_q(x5), l5: a5: RSTR(h51), l5: a5: BODY(h52), l6: a6: _mat_n_l(x6),  
h01 =q l1, h51 =q l6  
x0 = x1 = x2 = x3, e3 = e41, x4 = x5 = x6, l1 = l2, l3 = l4
```

Highly underspecified RMRS output:

```
l0: a0: _the_q(x0), l1: a1: _fat_j(x1), l2: a2: _cat_n(x2), l3: a3: _sit_v(e3), l4: a4: _on_p(e4),  
l5: a5: _a_q(x5), l6: a6: _mat_n(x6)
```

Copestake (2007): use POS tags rather than a lexicon, and get what relations we can from the grammar.



# Minimal recursion semantics (MRS)

- RMRS-style representations are used in a lot of projects these days.
- Standard composition algorithm not incremental.
- Incremental versions by Schlangen et al. (may discuss in a later week)
- We can try it ourselves using the DELPH-IN project web site—implemented with the “English Resource Grammar”.

# Lots of open questions!

Just for example:

- What do about raising constructions? “I want (Brutus) to stab Caesar.”
- Modals? “Brutus may have stabbed Caesar in the agora.” — possible world semantics!!!
- Relative clauses: “The man who Caesar offended stabbed him.”
- And, of course, an actual incremental semantic construction algorithm. . .

# Lets try some of our own

- Brutus often stabs Caesar in the chest in the agora.
- Some person often stabs Caesar.
- Every senator who stabbed Caesar is angry.
- Mark Antony saw that every senator stabbed Caesar.
- Brutus wants to stab Caesar.